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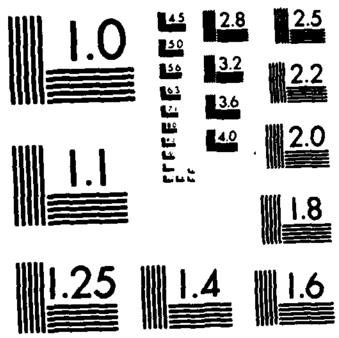

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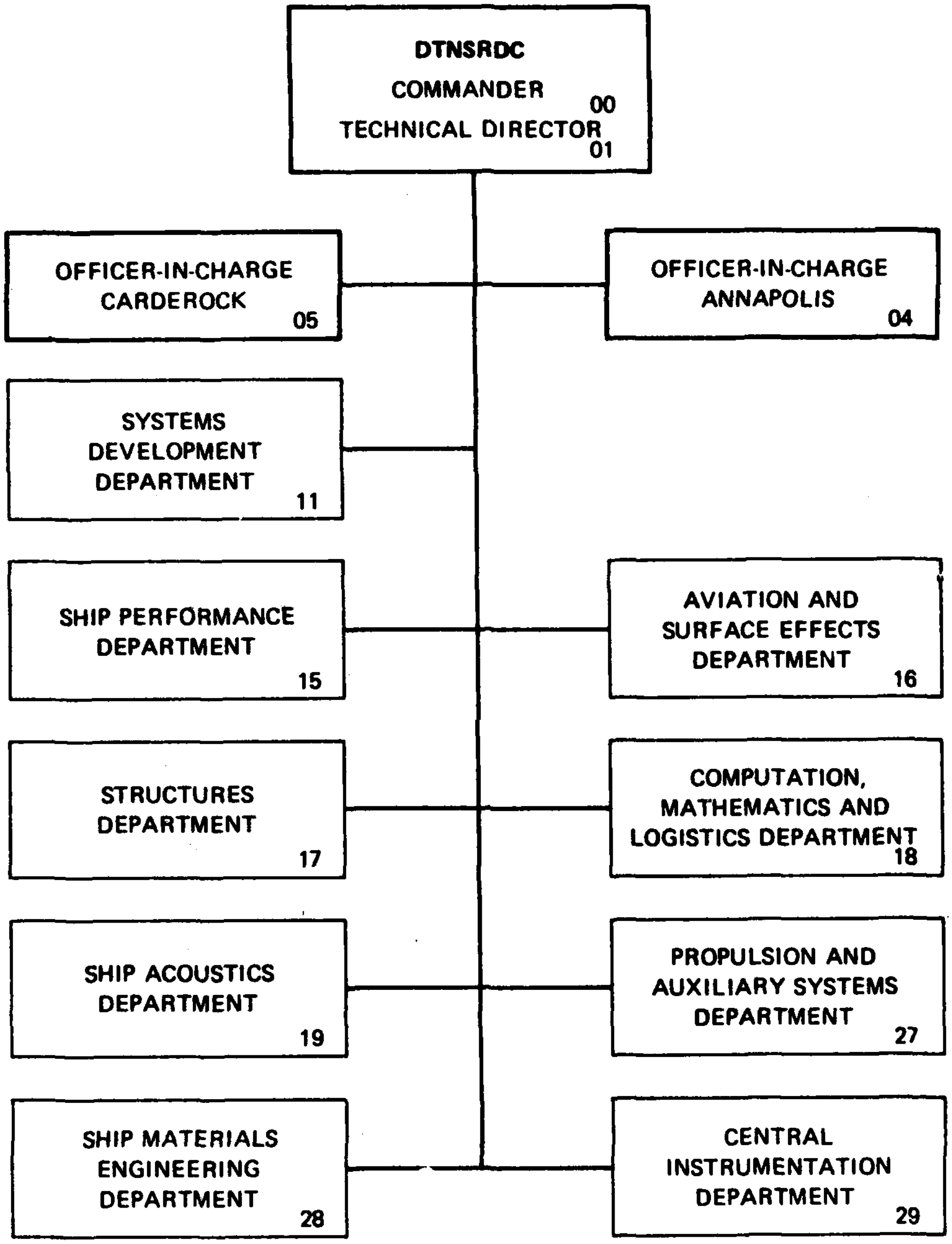

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Project Number 62543N
Sub-Project SF-43-421-301
Work Unit 1506-103

TABLE OF CONTENTS

ADMINISTRATIVE INFORMATION

Funds were provided by the Surface Ship Hydromechanics Program under Project Number 62543N, Block Number SF-43-421-301. The work was performed at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) where Work Unit Number 1506-103 was used to identify the work.

EXTENSION OF THE BALES SEAKEEPING RANK FACTOR CONCEPT

by

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ABSTRACT

An additional term for the equation used to predict the Bales seakeeping rank factor R is described. This new term incorporates the effect of displacement, thus extending the usefulness of the predictor equation. Discussion and example applications of the new equation are given.

INTRODUCTION

The original work of Bales[1] on the seakeeping rank factor, R, was a milestone paper of particular interest to the naval architect, since it represented a breakthrough in an area for which no essential progress had been reported over the last 20 years. A means was now available for evaluating, and in fact ranking, ships in a quantitative sense, more specifically ship underwater hulls, on the basis of their seakeeping characteristics. (It should be noted that the seakeeping characteristics included in the R factor are vertical relative and absolute motions and accelerations of various stations and a slamming index, all calculated in head seas for a range of speeds and sea states.) Adding further to the value of the R factor, an equation was developed to predict R factor values based on six ship underwater hull characteristics. The previous work dealt with a group of 20 destroyer type ships all normalized to 4300t displacement. Based on the R factor predictor equation and the limits of the six ship characteristic values for

the group of 20 ships, values for the six characteristics were chosen that defined an 'optimum' ship.

Subsequent work by Bales and Cieslowski[2] describes the generation of an 'anti-optimum' hull. In that work, extensive calculations were carried out using the Navy Standard Ship Motion Program, for a range of speeds, headings, and sea states, of nine responses. These calculations were done for a series of geosims of the 'optimum' and 'anti-optimum' hull. These results were then used to establish ranges of operability index values as a function of displacement.

The operability index values are a function of the particular responses chosen and especially of the limiting values chosen for each response which are based on specified operations. However, for many applications the R factor may prove to be of value particularly when the details of ship missions and systems, which are required for the calculation of operability indices, are not available.

The present work will discuss a means of calculating R factors based on a more complete hull form description, rather than predicting R using only six ship hull characteristics. This method will then be used in an investigation of the effect of displacement on R factor values. Thus a means will be developed of comparing the seakeeping characteristics of different size destroyer type ships. This will make possible quantitative studies of the effect of increased displacement on improving seakeeping characteristics. Further, the present work will extend the R factor predictor equation to include the effect of displacement.

R FACTOR CALCULATION

For both the present effort and planned future work, a means of more quickly and efficiently calculating R factor values based on a hull form description was required. Since, as described in Bales,[1] the R factor essentially includes only pitch, heave, and related motions in head seas; a simple seakeeping program is entirely adequate. That chosen is described in Loukakis.[3] Lewis forms, and the MIT bulb are used to describe the hull form. Comparison with results for ships using Lewis forms in Bales[1] shows excellent agreement, e.g., an R factor of 6.53 for Bales Hull 14 which corresponds to R factor of 6.56 for the same ship using the present calculation.

The present program requires ship length as well as beam, draft and sectional area for 20 stations. Also included as a variable is a scale factor which allows R factors for geosims of a parent hull to be calculated. The results of interest are R factors and calculated displacements. It should be noted that the R factors are calculated as described in Bales.[1] Except for $(C_S)_3$, the average responses are inverted after being divided by their respective minima. This was also done in producing the results shown in Bales,[1] although not fully clarified in that text.

VARIATION OF R WITH DISPLACEMENT

Using the program described in the previous section, the variation of R with displacement for a number of ships was studied. Seakeeping computations were carried out and R's based on these results were then calculated. The R predictor equation was not used. Figure 1 shows the results. Each line represents R factor values for a series of geosims of a parent hull. 21N is

an 'optimum' hull form, Hull 14 is a representative modern destroyer hull form, and 22N is an 'anti-optimum' hull. The normalization factors used here are the same as those used in the original work, thus R factors greater than 10 and less than 1 are to be expected.

The figure indicates a 8000t version of each of the hulls would have the following R's:

Hull	R
21N (Optimum)	23.7
14 (Destroyer)	18
22N (Anti-optimum)	8.5

Hull 14 is seen to be closer to the optimum then the anti-optimum, but improvement is still possible in seakeeping performance.

Of perhaps even greater interest is the interpretation of the figure which shows the displacement required to achieve a desired R value, for example, if an R value of 9 is desired the hulls would require the following displacement:

Hull	Displacement
21N	3620t
14	5030t
22N	8210t

This shows quite dramatically the difference between the seakeeping performance of a very good hull form compared to that of a very bad hull form. A 3620t version of the good hull form would achieve the same seakeeping

performance as an 8210t version of the bad hull form; the bad ship requiring more than twice the displacement for the same performance.

Since calculated R's rather than predicted R's are being used, it is possible to compare R's for different displacement, that is non-normalized ships. For example,

Ship	Hull Geosim	Displacement	R
A	21N	4000	10.4
B	14	6000	11.8
C	22N	7000	6.3

Here Ship B would have the best seakeeping performance as measured by the R factor. Ship A is second, even though it has the best hull form, because the additional displacement of Ship B more than makes up the difference. Ship C is worst, its greater displacement not being able to overcome the disadvantage of its hull form.

EXTENDED R FACTOR

Using the results shown in Figure 1, an additional term can be added to the R factor predictor equation to incorporate the effect of displacement. In order to maintain consistency with the other terms, a linear term in a nondimensional ship characteristic is required. Using normalized displacement variation and the average of the slopes of the 21N and 22N curves, this additional term is given by:

$$\frac{12.9\ (\Delta - 4300)}{4300}$$

where displacement Δ is in tonnes. The R factor predictor equation thus becomes:

$$\hat{R} = 8.422 + 45.104\ C_{WF} + 10.078\ C_{WA} - 378.465\ T/L + 1.273\ c/L$$
$$- 23.501\ C_{VPF} - 15.875\ C_{VPA} + 12.9\ \frac{(\Delta - 4300)}{4300}$$

where all notation is as in Bales.[1] The range of displacement is limited to 3000t to 9000t.

CONCLUSIONS

The usefulness of the R factor has been increased by extending the predictor equation to include displacement. It should however, be remembered that it is always dangerous to attempt to summarize such a complicated phenomenon as seakeeping in a single number. All the caveats concerning the R factor cited in Bales[1] still apply and should be carefully reviewed before any application is attempted. Using R factors based on seakeeping computations avoids the problem of the limited range of the input parameters associated with the predictor equation, but caution is still required.

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Funds were provided by the Surface Ship Hydromechanics Program under Project Number 62543N, Block Number SF-43-421-301. The work was performed at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) where Work Unit Number 1506-103 was used to identify the work.

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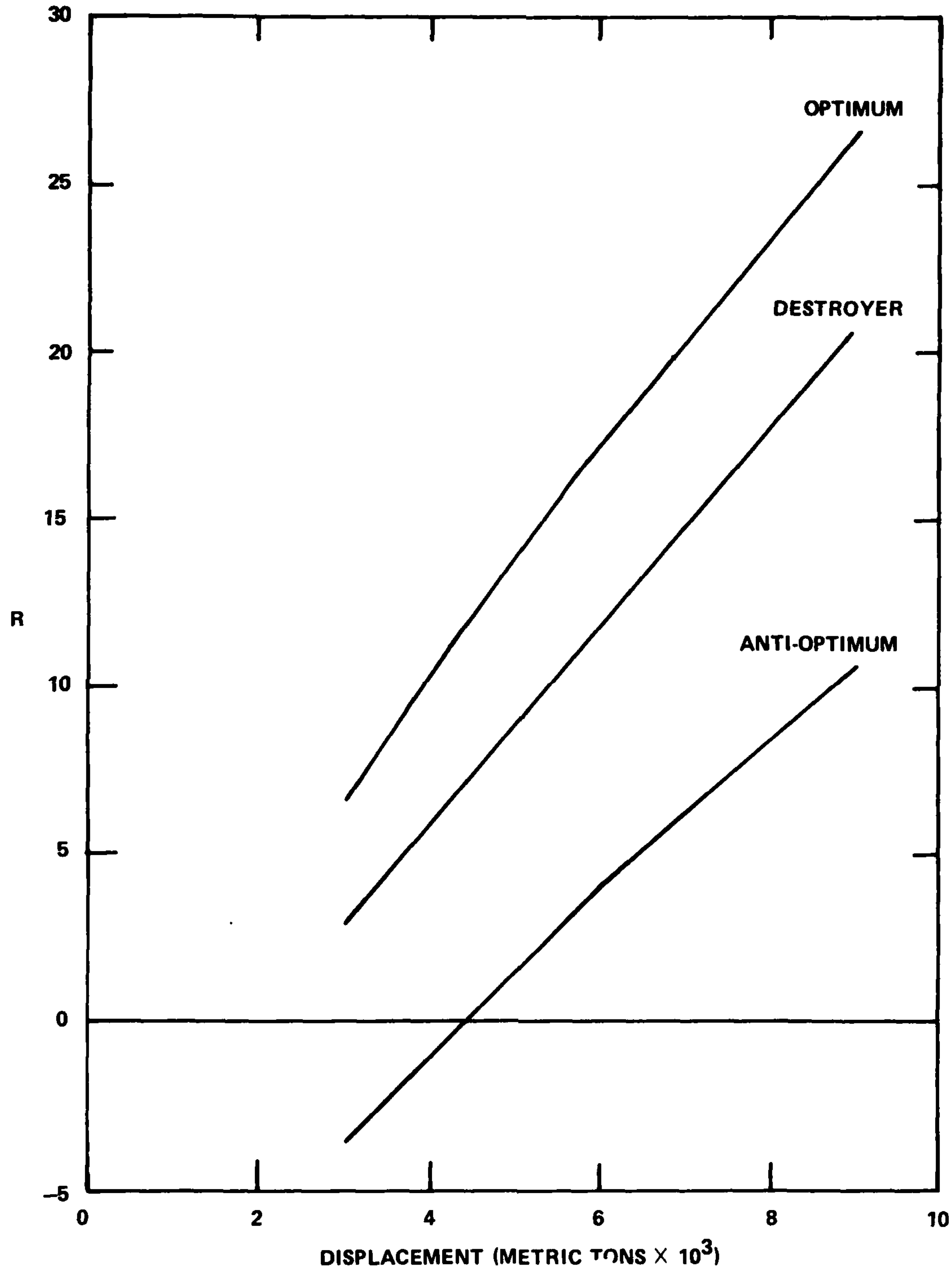

Figure 1 - Variation of R with Displacement

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